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TEACHERS' KNOWLEDGE AND BELIEFS ABOUT GAMIFICATION IN PHYSICS CLASSROOMS

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Abstract. *Gamification has been gaining attention in STEM education for its potential to enhance student engagement and learning outcomes. Teachers' acceptance and effective use of gamification depend on their knowledge and beliefs about its implementation. This study employs a mixed-method design to explore Croatian physics teachers' knowledge and beliefs about gamification. In the first phase, semi-structured interviews were conducted with five primary and five secondary school teachers. Insights from these interviews informed the development of an online questionnaire in Google Docs. The final questionnaire consisted of three parts: demographic information (including an open-ended question defining gamification), 16 Likert-type items measuring knowledge and beliefs, and three open-ended questions on key elements, technological tools, and challenges in applying gamification in physics classrooms. In the second phase, quantitative data were collected from 230 primary and secondary school physics teachers, providing a robust sample to examine variations in knowledge and beliefs about gamification. Findings reveal that most teachers possess basic knowledge and hold positive beliefs regarding gamification, although significant differences emerge based on age, teaching experience, and school type. These results underscore the need for tailored professional development programs. The study emphasizes the importance of designing support strategies that accommodate diverse teacher profiles.*

Keywords: *gamification knowledge, mixed-method design, physics teachers, STEM education*

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Introduction

Comprehending physics is crucial in today's rapidly changing technological landscape, as it underpins the innovations shaping our world. As a foundational school subject, physics explains the laws governing the natural world and provides the basis for many technological advancements (Bao & Koenig, 2019). Additionally, it promotes the development of essential skills in learners, such as problem-solving, technological proficiency, and an innovative mindset – all of which are crucial for navigating the challenges of an increasingly digital society.

Moreover, physics education plays a central role in preparing individuals for careers across a wide range of fields, industries, and organizations. As such, its objectives extend beyond imparting subject-specific knowledge to also fostering a broad set of competencies, including knowledge, skills, attitudes, and values. This shift reflects the evolving demands of modern educational and professional environments, as scientific reasoning and digital literacy have become integral to physics curricula worldwide over the past decade (Asrizal et al., 2023; Thoms et al., 2023). However, many physics programs have not sufficiently emphasized the multidisciplinary applications of physics or addressed the broad professional opportunities available to graduates. This lack of alignment has highlighted the need for educational systems to integrate transdisciplinary and interdisciplinary approaches in physics classrooms (Cayless & Jordan, 2024).

One approach to teaching physics that supports these goals is the integration of gamification. This strategy applies game design elements to non-game contexts and has been explored as a potential solution for enhancing student engagement and learning outcomes in physics education. Previous studies have shown that gamification can effectively boost motivation, improve cognitive outcomes, and address challenges such as disengagement in STEM subjects (Dichev & Dicheva, 2017; Swacha, 2021).

However, despite the growing interest in gamification as a strategy to enhance physics education, limited attention has been given to understanding teachers' knowledge and beliefs about gamification and how these factors influence its implementation in the classroom. Teachers play a pivotal role in the success of innovative teaching strategies, yet their beliefs and knowledge about gamification remain largely unexplored.

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Theoretical Background

Physics education plays a pivotal role in addressing societal challenges and fostering skills necessary for thriving in an interconnected world. In this context, the Physics for Society at the Horizon of 2050 initiative emphasizes equipping individuals with scientific literacy and problem-solving abilities to actively participate in democratic processes and contribute to a diverse scientific workforce (Hidalgo & Lee, 2022). Similarly, the European Physics Society's Physics Education Division underscores that investing in physics education today ensures communities are prepared for the demands of a technology-driven future (Byun & Lee, 2014; Hidalgo et al., 2024).

Physics education serves a dual purpose: it prepares future physicists while also fostering scientifically literate citizens who are capable of understanding and addressing complex global challenges (DeWitt, 2016). However, many students struggle with physics concepts due to deeply ingrained misconceptions formed through everyday experiences (McDermott & Redish, 1999). These misconceptions often conflict with the scientific models taught in schools, making the subject particularly difficult for students to master (Novak & Gowin, 1984).

Interdisciplinary approaches, especially within STEM education, have proven effective in cultivating cross-cutting skills such as collaboration, self-regulation, problem-solving, creativity, communication, and critical thinking (McLoughlin et al., 2020). At the same time, constructive approaches to education emphasize active, team-based learning, which allows students to build knowledge and develop advanced cognitive abilities, such as scientific reasoning and deep subject understanding. These approaches have been shown to be particularly effective when complemented by modern technologies that enhance access to information and create more efficient learning environments (Bao & Koenig, 2019).

However, the global shortage of qualified primary and secondary school physics teachers to implement the above approaches in classrooms remains a significant issue, adversely affecting the quality of physics education (Cayless & Jordan, 2024; Erceg et al., 2023). Addressing these challenges requires innovative teaching practices that align with modern educational needs and emphasize the relevance of physics in solving real-world problems.

What is the situation in the field of physics education in Croatia? Physics is perceived as one of the least popular and most challenging subjects. This perception is largely attributed to its abstract, math-intensive nature and the volume of content presented in traditional teaching methods (Marušić & Sliško, 2009; Simel, 2016). Disinterest in physics is frequently associated with the subject's perceived dullness, although higher-achieving students tend to express greater enthusiasm (Ćosić, 2015; Simel, 2016). Many students appreciate physics for its experimental aspects and its contribution to scientific thinking but rarely pursue it as a career. Additionally, while girls tend to outperform boys academically, boys report lower motivation to engage with physics (Jugović, 2010). These trends reflect a broader, decades-long decline in interest in science education globally (Simel, 2016). Meanwhile, physics teachers report that while they can adapt to the current circumstances, they still struggle to motivate students to engage and learn (Štibi et al., 2021).

Outside of Croatia, gamification—the application of game design elements to non-gaming contexts—has emerged as a promising strategy for fostering student engagement (McGonigal, 2010). By incorporating game elements such as goals, feedback, and challenges, gamification motivates students to pursue learning actively (Deterding et al., 2011).

Research has demonstrated that gamified teaching techniques can increase engagement, improve motivation, and even lead to behavioral changes (Dichev & Dicheva, 2017; Dziob, 2018; Su, 2019; Susman & Pavlin, 2020; Swacha, 2021). Some recent science education studies have explored free-choice games, which allow students and the public to implicitly learn scientific concepts, including physics (TERIC, 2020; Vieyra et al., 2020). However, research has also highlighted that these effects can vary based on individual student characteristics.

Research in the field of gamification is highly dynamic. Jantakoon et al. (2024) have analyzed trends in gamification research, identifying significant growth in its application within STEAM education and highlighting its impact on collaborative learning. For example, gamification combined with team-based learning has been shown to improve the educational experience for students with and without special needs (Brecl et al., 2024). Meanwhile, Kam and Umar (2023) have explored the differing impacts of gamification on high- and low-achieving students, emphasizing the need for adaptive strategies to ensure equitable benefits across diverse learner groups.

From the literature review, it is evident that gamification has also been successfully implemented in diverse educational settings, such as professional foreign language training (Zvarych et al., 2019), business informatics using Moodle platforms (Paľová & Vejačka, 2022), engineering fundamentals (Song et al., 2017), and physics courses focused on electric resistors for second-year students (Forndran & Zacharias, 2019). Inquiry-based approaches, like the 5E model and escape rooms, have incorporated gamified elements to foster curiosity and active learning in

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science classes (Rusevska et al., 2024). Moreover, during the era of social distancing, studies have emphasized the sustainability and effectiveness of gamified learning environments (Musyaffi et al., 2022). Beyond these approaches, tools like Socrative for assessments (Perera & Hervás-Gómez, 2021), interactive gaming platforms (Soboleva et al., 2018), and augmented reality in STEM education (Brooks et al., 2019) demonstrate the diverse applications of gamification in enhancing teaching and learning outcomes. It has been reported that gamification is particularly effective as a teaching tool for intrinsically motivated students (Buckley & Doyle, 2016). In higher education, gamification has been applied to enhance academic knowledge acquisition and soft skills development, ensuring students remain engaged and enjoy learning (Forndran & Zacharias, 2019; Jantakoon et al., 2024).

While meta-analyses have confirmed the positive cognitive effects of gamification, motivational and behavioral outcomes vary depending on the context and design (Sailer & Homner, 2020). Similarly, Bai et al. (2020) have reported varying outcomes. The success of gamification depends heavily on careful design and implementation. Poorly constructed gamified activities can lead to negative outcomes, such as anxiety, frustration, or a perceived lack of value.

In the design and successful integration of gamification into teaching practices, teachers play a central role. Their knowledge and beliefs significantly influence how gamification is implemented in classrooms (Ketelhut & Schifter, 2011), revealing its potential to enhance both engagement and skill development. For instance, López et al. (2021) have found that nearly 80% of mathematics teachers view gamified activities in STEAM education as more effective than traditional methods, particularly in fostering positive emotional attitudes toward mathematics and developing mathematical literacy. This highlights the broader applicability of gamification across subjects and its potential to address skill gaps in STEM education.

However, many teachers lack the training and professional development opportunities to effectively implement gamified strategies (Mukh et al., 2023). Research has highlighted that providing teachers with the skills to navigate online resources and design gamified learning activities is critical for fostering future-ready science education (Bellocchi et al., 2024; Walraven et al., 2009).

This leads to the research problem addressed in this study: the limited understanding of teachers' knowledge and beliefs about gamification in physics education and its implications for effective implementation. While gamification has shown promise in enhancing engagement and learning outcomes, there remains a gap in understanding how teacher-related factors influence its success.

The aim of this study was to explore teachers' self-assessed knowledge and beliefs about gamification in physics education. By addressing these aspects, the study seeks to provide valuable insights into the factors that influence the adoption and effectiveness of gamification strategies in teaching.

The research specifically addressed the following research questions:

1. How do teachers self-assess their knowledge and beliefs about gamification?
2. Are there significant differences in knowledge and beliefs about gamification based on teachers' age, gender, work experience, and school type?
3. What effective game elements, useful tools, and challenges do teachers identify in relation to implementing gamification?

Research Methodology

General Background

To address the posed research questions, a descriptive cross-sectional study has been conducted (Cohen et al., 2002). The research employed a mixed-methods approach, emphasizing quantitative data collection and analysis, complemented by qualitative insights (Ary et al., 1972; Johnson & Christensen, 2019). The study has been conducted from February to April 2024 and targeted a substantial sample of physics educators to provide a broad understanding of gamification in physics education in Croatia.

The study has been conducted using an online questionnaire. It consisted of open-ended questions and Likert-type items. Quantitative data gathered through this facilitated an analysis of teachers' familiarity with gamification, the specific gamified elements they have used in their physics classrooms, and their knowledge and beliefs about gamification's impact on student engagement and interest. Additionally, qualitative data from open-ended questions (Creswell & Guetterman, 2019) provided deeper insights into the challenges teachers face in implementing gamification, their preferences for gamified elements in physics education, and the technological tools or applications they find most effective.

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It should be emphasized that the study has been grounded in a theoretical framework that highlights teachers' knowledge and beliefs about gamification as a critical factor influencing the successful integration of innovative teaching practices. The scope of the study extends to exploring the practical applications of gamification and its implications for improving physics education.

Sample

A total of 230 physics teachers participated in the study, representing 25% of all physics teachers in the Republic of Croatia (N = 922) for the 2023–2024 school year. The sample size was calculated using an online sample size calculator with the following parameters: confidence level of 95%, margin of error of 5%, and population proportion of 50%. Based on these settings, the sample size for a population of 922 physics teachers was determined to be 272. Although the actual sample size of 230 respondents is below the determined, it still ensures a high level of reliability for the study's findings. Research indicates that achieving at least 80% of the calculated sample size provides sufficient statistical power and validity in survey-based studies (Andrade, 2020).

The demographic information of the respondents is presented in Table 1. The respondents represented diverse educational and professional backgrounds: 53% worked exclusively in primary schools, 40% in secondary schools, and 7% taught at both primary and secondary schools. Among the respondents, 81% (187 teachers) held a university degree in physics teaching, either independently or combined with another subject; 10% (24 teachers) had completed a degree in physics/astrophysics/biophysics/computer physics with additional pedagogical training; 6% (13 teachers) held degrees in other fields with added pedagogical competencies; and 3% (6 teachers) reported having a master's degree or doctorate in physics, educational physics, or didactics.

The respondents' age distribution and work experience ensured a balanced representation of the teaching population (Table 1). Two respondents did not provide their age, which accounts for the discrepancy between the total sample size of 230 and the sum of the age distribution. This missing data was considered during the statistical analysis to ensure an accurate and reliable interpretation of the results.

Table 1
Respondents' Demographic Information

Category	Subcategory	Percentage	Number of Teachers
School Type	Primary school only	53	122
	Secondary school only	40	92
	Both primary and secondary school	7	16
Educational Qualification	University degree in physics teaching (or combined with another subject)	81	187
	Degree in physics/astrophysics/biophysics/computer physics with additional pedagogical training	10	24
	Degrees in other fields with added pedagogical competencies	6	13
	Master's degree or doctorate in physics, educational physics, or didactics	3	6
Age Distribution	Under 25	1	3
	25–34	17	39
	35–45	34	78
	46–54	33	76
	55 or older	14	32
	No response	—	2
Work Experience	Less than 1 year	1	3
	1–5 years	14	33
	6–10 years	14	31
	11–15 years	19	44
	More than 15 years	52	119

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Participation in the survey was voluntary and anonymous, with respondents providing informed consent for their data to be used for research purposes. The study was conducted in compliance with the Declaration of Helsinki and was approved by the Ethics Committee of the University of Split, Faculty of Science (CLASS: 042-01/24-01/00020, NUMBER: 2181-204-02-07-24-00004, 8 July 2024).

Instrument and Procedures

The data for this study have been collected using an online questionnaire designed and administered via Google Docs. The development of the questionnaire has followed a rigorous two-phase process to ensure its relevance and reliability. In the first phase, a qualitative study has been conducted, consisting of semi-structured interviews with five primary school teachers and five secondary school teachers, selected through conventional sampling (Bornstein et al., 2013). These interviews have been conducted via video conference, phone, or in person. The primary aim of this phase was to identify relevant themes and questions that would inform the design of the quantitative portion of the research. Insights from these interviews have provided a foundation for the structure and content of the online questionnaire.

The final form of the questionnaire includes an introductory section, followed by three main sections to capture a comprehensive range of data. In the introductory section, respondents were informed about the survey's objectives and assured that the collected data would remain confidential and anonymous, with findings used solely for research purposes.

The first section of the questionnaire collects demographic information and preliminary opinions about gamification. It comprises questions regarding gender, age, work experience, the type of school where respondents work (primary or secondary), and their academic qualifications. Additionally, this section includes an open-ended question designed to explore the respondents' understanding of gamification. Respondents are presented with four options for defining gamification but also have the opportunity to articulate their own definition if none of the provided options align with their views.

The second section of the questionnaire focuses on teachers' knowledge and beliefs about gamification in physics education through 16 Likert-type items. These items address various aspects of gamification and its application, with responses recorded on a five-point scale ranging from 'strongly disagree' to 'strongly agree'. This section aims to capture quantitative data regarding teachers' familiarity with gamification and their beliefs on its effectiveness.

The third section of the questionnaire incorporates three open-ended questions designed to gather qualitative insights into teachers' knowledge and beliefs about gamification. These questions ask respondents to identify key elements of gamification they consider most effective in the physics classroom, technological tools or applications they deem useful for supporting gamification, and the specific challenges they perceive as common in implementing gamification in physics education. This section also allows respondents to share detailed and nuanced viewpoints that are not captured in the previous sections of the questionnaire.

The questionnaire is distributed to all physics teachers in Croatia via their official school email addresses, which school principals provide. The instrument remains open from February 1, 2024, to May 1, 2024. In mid-March, a reminder email is sent to encourage additional participation. This approach ensures that all teachers in the population have an equal opportunity to participate in the study, maximizing inclusivity and representativeness.

Several measures have been taken to ensure the validity and reliability of the questionnaire. The semi-structured interviews in the qualitative phase have ensured content validity by directly identifying key aspects of gamification from educators. The initial questionnaire version has been pilot tested with a small group of physics teachers who are not part of the main study. This has helped refine the items and eliminate any ambiguities. A Cronbach's alpha coefficient has also been calculated for the Likert-type items to assess internal consistency, with results indicating satisfactory reliability ().

This methodical approach ensures that the questionnaire is reliable and valid, providing a robust tool for exploring physics teachers' knowledge, beliefs and practices regarding gamification. By combining qualitative and quantitative methods, the study gains a comprehensive understanding of the topic while ensuring the psychometric soundness of the instrument (Cohen et al., 2002). The questionnaire is available in the repository at the following link: https://bit.ly/Anketa_igrifikacija.

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Data Analysis

The data collected in Google Forms have been imported and analyzed in the IBM SPSS 26 software package (Pallant, 2020). Different types of statistical analysis have been used, including also t-tests, ANOVA, and regression analysis.

A principal component factor analysis using Varimax rotation has been conducted to ascertain the scales' factor structure on teachers' knowledge and beliefs toward gamification in physics education (Table 2). The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was KMO = 0.902, indicating excellent suitability for factor analysis. Bartlett's Test of Sphericity was significant, $\chi^2(120) = 2446.318$, $p < .001$, suggesting that the correlation matrix was not an identity matrix and that factor analysis was appropriate. The factor analysis has shown that two factors explain 63% of the variation, according to the Scree plot criterion and the Kaiser-Guttman criterion (eigenvalues greater than 1).

Table 2
The Scales' Factor Structure on Teachers' Knowledge and Beliefs Toward Gamification in Physics Education

Item	Knowledge	Beliefs
1. I am familiar with the different elements of gamification that can be used in physics lessons.	.817	
2. I have a good understanding of the concept of gamification in the context of physics lessons.	.809	
3. I frequently participate in training courses on the use of gamification in physics lessons.	.731	
4. I often use rewards or points as part of a gamification approach in physics lessons.	.767	
5. I frequently incorporate competitive elements or team dynamics as part of gamification in physics lessons.	.746	
6. I regularly adapt gamification activities to the different levels of knowledge of my students.	.704	
7. I make extensive use of technological tools or applications as part of gamification in physics lessons.	.686	
8. I believe that gamification promotes students' motivation during physics lessons.		.851
9. I believe that gamification encourages collaboration between students in physics lessons.		.844
10.I find that gamification sparks students' interest in the further study of physics concepts.		.842
11. I believe that gamification encourages students to ask more questions and seek further explanations of physics concepts.		.810
12. I think gamification helps to promote students' understanding of physical concepts.		.801
13. I believe that gamification improves the acquisition of practical skills in the field of physics.		.789
14. I observe that students react positively to the introduction of gamification activities in class.		.780
15. I believe that gamification encourages students' independence in physics research outside the classroom.		.774
16. I believe my knowledge of gamification significantly influences the successful application of this method in physics lessons.		.534
Characteristic root	32.819	7.211
% of variance	17.62	62.69
Cronbach alpha	.884	.928

The Kolmogorov-Smirnov test has been applied to assess the normality of distributions, and skewness and kurtosis values have been evaluated. Pearson's correlation coefficient has been employed to examine the association among the variables.

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Research Results

Table 3 presents the results of the descriptive analysis of both scales (knowledge and beliefs). The data indicate that teachers have knowledge of gamification since, on average, they assess the statements neutrally. However, they believe that gamification contributes or could contribute to increasing motivation and collaboration, thereby improving the educational outcomes in physics lessons. The variable distributions greatly diverge from the normal distribution. Therefore, the kurtosis and skewness of the distributions, whose recommended values range between -1 and 1, have been examined. Since all variables meet this criterion, it is concluded that parametric statistics methods can be applied to further data processing (Hair et al., 1998). The p-value represents the probability of observing the given data or something more extreme, assuming the null hypothesis is true. This value is used to determine statistical significance, with a threshold (commonly .05) indicating whether the results are unlikely to have occurred by chance.

Table 3

Results of the Descriptive Analysis of Both Scales: Knowledge and Beliefs About Gamification

Scale	Min	Max	*M*	*SD*	*Z*	*p*	Skewness	Kurtosis
Knowledge	1.00	5.00	2.71	0.83	.062	.032	0.067	0.192
Beliefs	1.00	5.00	3.48	0.71	.067	.015	0.611	0.973

Note. M = Mean; *SD* = Standard Deviation; I = Kolmogorov-Smirnov test statistic; *p* = Significance level. Skewness and Kurtosis describe the distribution shape. A significance level (p) below .05 suggests a deviation from normality.

To test whether younger teachers' knowledge and beliefs about gamification are statistically significantly higher than those of older teachers and whether gender, professional experience and school type play a statistically significant role in their knowledge and beliefs about this strategy, a one-way analysis of variance (ANOVA) has been conducted. The requirements for conducting an ANOVA are as follows: the dependent variable must be continuous, the variables must be normally distributed, there must be no extreme results, and sphericity must be met. The analysis is not highly sensitive to violating the normality assumption, especially if the groups comprise 100-200 or more respondents (Tabachnick & Fidell, 2007). However, the results may be unreliable if the variances are not homogeneous; therefore, Levene's test has been conducted, which has not been significant.

Table 4 represents the data from the descriptive analysis for each of the 16 Likert-type items on the number of respondents, mean score and standard deviation (Brooks et al., 2019).

Table 4

Results of the Descriptive Analysis of 16 Likert-type Items from the Online Gamification Questionnaire Provided by Physics Teachers in Croatia

Scale	Item	*N*	Min	Max	*M*	*SD*
Knowledge	1	230	1	5	2.77	0.992
	2	230	1	5	2.72	0.958
	3	230	1	5	2.32	1.106
	4	230	1	5	2.65	1.130
	5	230	1	5	2.74	1.049
	6	230	1	5	3.36	0.913
	7	230	1	5	3.61	0.931

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Scale	Item	*N*	Min	Max	*M*	*SD*
Beliefs	8	230	1	5	3.76	0.891
	9	230	1	5	3.58	1.037
	10	230	1	5	3.77	0.867
	11	230	1	5	3.06	1.018
	12	230	1	5	3.43	0.921
	13	230	1	5	2.70	0.998
	14	230	1	5	3.38	0.926
	15	230	1	5	3.31	0.965
	16	230	1	5	3.37	0.904

Note. Min = Minimum; *Max* = Maximum; *M* = Mean; *SD* = Standard Deviation. Responses were collected from 230 participants. Items 1–7 measure knowledge, while items 8–16 measure beliefs. The Likert scale ranged from 1 (Strongly Disagree) to 5 (Strongly Agree).

The responses to the statements regarding knowledge and beliefs about gamification have been measured on a 5-point Likert scale, with scores ranging from 2.32 (item 3) to 3.61 (item 7) for knowledge and 2.70 (item 13) to 3.77 (item 10) for beliefs.

For item 3, "I frequently participate in training courses on the use of gamification in physics lessons," the average score is the lowest – 2.32. This suggests that, on average, teachers do not frequently engage in training courses related to gamification. This lower score indicates a potential gap in professional development, implying that physics teachers may lack the readiness or training necessary to effectively apply gamification techniques in their teaching. In contrast, for item 7, "I make extensive use of technological tools or applications as part of gamification in physics lessons," the average score is the highest – 3.61. This suggests that, on average, teachers are more likely to incorporate technological tools and applications into their physics lessons as part of gamification, indicating a relatively higher level of engagement with technology-driven gamified teaching methods.

For item 13, "I believe that gamification improves the acquisition of practical skills in the field of physics," the average score was the lowest among the belief items – 2.70. This score is closer to the neutral midpoint (3), indicating that teachers are somewhat uncertain or less convinced about gamification's effectiveness in improving practical physics skills. This suggests that, while gamification may be seen as effective in sparking student interest, its impact on developing practical skills is viewed with less confidence. On the other hand, for item 10, "I find that gamification sparks students' interest in the further study of physics concepts," the average score was the highest among belief items – 3.77. This relatively high score suggests that teachers generally believe gamification plays a significant role in sparking students' interest in further studying physics concepts. It indicates that teachers view gamification as an engaging tool that enhances students' curiosity and motivation. Additionally, item 8, "I believe that gamification promotes students' motivation during physics lessons," scores highly, with an average of 3.76, reflecting optimism about the potential benefits of gamification in the classroom as well.

To examine whether statistically significant differences exist in each Likert-type item according to gender, age, work experience and school type, the Independent-Samples t-test and One-Way ANOVA have been conducted (Table 5).

Table 5
Independent-Samples t-Test and One-Way ANOVA for Differences in Gamification Score

Item	Gender	Age	Work Experience	School Type
1	.790	.606	.994	.282
2	.789	.561	.897	.095
3	.935	.945	.424	.244
4	.332	.461	.634	.721
5	.353	.184	.575	.291

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Item	Gender	Age	Work Experience	School Type
6	.140	.104	.086	.064
7	.383	.149	.059	.604
8	.576	.374	.284	.209
9	.464	.133	.066	.410
10	.326	.046	.031	.786
11	.290	.011	.023	.944
12	.327	.010	.001	.280
13	.327	.386	.041	.357
14	.738	.398	.054	.555
15	.471	.946	.161	.212
16	.624	.302	.011	.556

Note. This table presents the results of the independent-samples t-test and one-way ANOVA examining statistically significant differences in Likert-type item scores on gamification among Croatian physics teachers. The analysis was conducted based on gender, age, work experience, and school type. The presented values are p-values indicating the statistical significance of the differences.

The independent-samples t-test and one-way ANOVA results indicate that demographic factors such as gender, age, work experience, and school type generally do not significantly influence responses to most items, as most p-values exceed the .05 significance threshold. However, age has shown a significant effect on items 10 (p = .046), 11 (p = .011), and 12 (p = .010), suggesting that age may influence beliefs related to these items. Experience has significantly affected items 10 (p = .031), 11 (p = .023), 12 (p = .001), and 16 (p = .011), highlighting the influence of professional background on these specific aspects. School type and gender do not significantly affect any item, indicating a limited influence of these factors in this analysis.

To examine whether statistically significant differences exist in the knowledge and beliefs scales about gamification as a teaching strategy in physics classrooms in relation to gender, age, work experience, and school type, a one-way analysis of variance with repeated measures ANOVA has been conducted (Table 6). Statistically significant differences in beliefs about gamification have been identified within groups with varying levels of work experience.

Table 6

One-Way ANOVA of Teachers' Knowledge and Beliefs About Gamification

Scale	A Source of Variability	*SS*	*df*	*MS*	*F*	*p*
Knowledge	Gender	.241	1	.241	.369	.544
	Age	.650	1	.650	.998	.319
	Work Experience	.420	1	.420	.642	.423
	School Type	2.467	2	1.234	1.909	.151
Beliefs	Gender	.503	1	.503	.921	.338
	Age	2.005	1	2.005	3.718	.055
	Work Experience	3.594	1	3.594	6.749	.010
	School Type	1.303	2	.652	1.196	.304

Note. This table presents the results of the one-way ANOVA analyzing Croatian physics teachers' knowledge and beliefs about gamification. The analysis was conducted based on gender, age, work experience, and school type. SS = Sum of Squares; df = Degrees of Freedom; MS = Mean Squares; F = F - ratio (ratio of variance); p = Significance Level. Statistically significant results are in bold ($p < .05$).

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For the knowledge about the gamification scale, the findings indicate that none of the demographic variables significantly influence Croatian physics teachers' knowledge levels. Specifically, the p-values for gender (p = .544), age (p = .319), work experience (p = .423), and school range (p = .151) all exceed the significance threshold of .05. In contrast, the beliefs about gamification scale presented a more nuanced picture. While gender (p = .338) and school range (p = .304) do not show significant effects, age (p = .055) approached the significance threshold, indicating a potential trend worth further exploration. Work experience has emerged as a significant factor influencing beliefs about gamification, with a p-value of .010.

A series of linear regression analyses have been conducted to examine the relationship between knowledge about gamification and physics teachers' beliefs about this strategy. The predictor variables include gender, work experience, school and age (control variables), while the criterion variables are knowledge about gamification and teachers' beliefs. The necessary assumptions have been checked to carry out the regression analysis, including multicollinearity and the absence of autocorrelation of the residuals. In no case is the tolerance coefficient lower than .01, and the variance inflation factor (VIF) value does not exceed 10. The Durbin-Watson test result is satisfactory, with a value of 2.001. The results of the series of linear regression analyses are presented in Table 7.

Table 7
Linear Regression for Scales Knowledge and Beliefs About Gamification

Scale	A source of variability	*SS*	*df*	*MS*	*F*	*p*
Knowledge	Age/School Type	2.938	2	1.469	2.281	.105
	Age/Gender	0.083	2	0.415	0.635	.531
	Age/Work Experience	0.691	2	0.345	0.528	.591
	Gender/School Type	2.605	2	1.303	2.017	.135
	Gender/ Work Experience	0.570	2	0.285	0.436	.647
	Work Experience/School Type	2.678	2	1.339	2.075	.128
Beliefs	Age/School Type	2.239	2	1.119	2.070	.129
	Age/Gender	2.696	2	1.348	2.502	.084
	Age/Work Experience	3.709	2	1.855	3.471	.033
	Gender/School Type	0.899	2	0.449	0.822	.441
	Gender/ Work Experience	4.679	2	2.339	4.414	.013
	Work Experience/School Type	3.732	2	1.886	3.393	.032

Note. This table presents the results of the linear regression analysis of physics teachers' knowledge and beliefs about gamification. The model includes a combination of two predictor variables selected from gender, work experience, school type, and age. *SS* = Sum of Squares; *df* = Degrees of Freedom; *MS* = Mean Squares; *F* = F - ratio (ratio of variance); *p* = Significance Level. Statistically significant results are in bold ($p < .05$).

The findings reveal that demographic variables do not have a statistically significant influence on teachers' knowledge about gamification. For instance, the interactions between age and school type (p = .105), age and gender (p = .531), age and work experience (p = .591), gender and school type (p = .135), gender and work experience (p = .647), and work experience and school type (p = .128) produced p-values that were greater than the significance threshold of .05. In contrast to knowledge, beliefs about gamification are significantly influenced by specific combinations of demographic variables. The interaction between age and work experience (p = .033) suggests that these factors collectively shape teachers' beliefs toward gamification. Similarly, the combination of gender and work experience had a significant effect (p = .013), highlighting that gender, in conjunction with work experience, plays a role in shaping beliefs. The interaction between work experience and school type is also significant (p = .032), indicating that teachers' work environment, when combined with their work experience, affects their beliefs about gamification.

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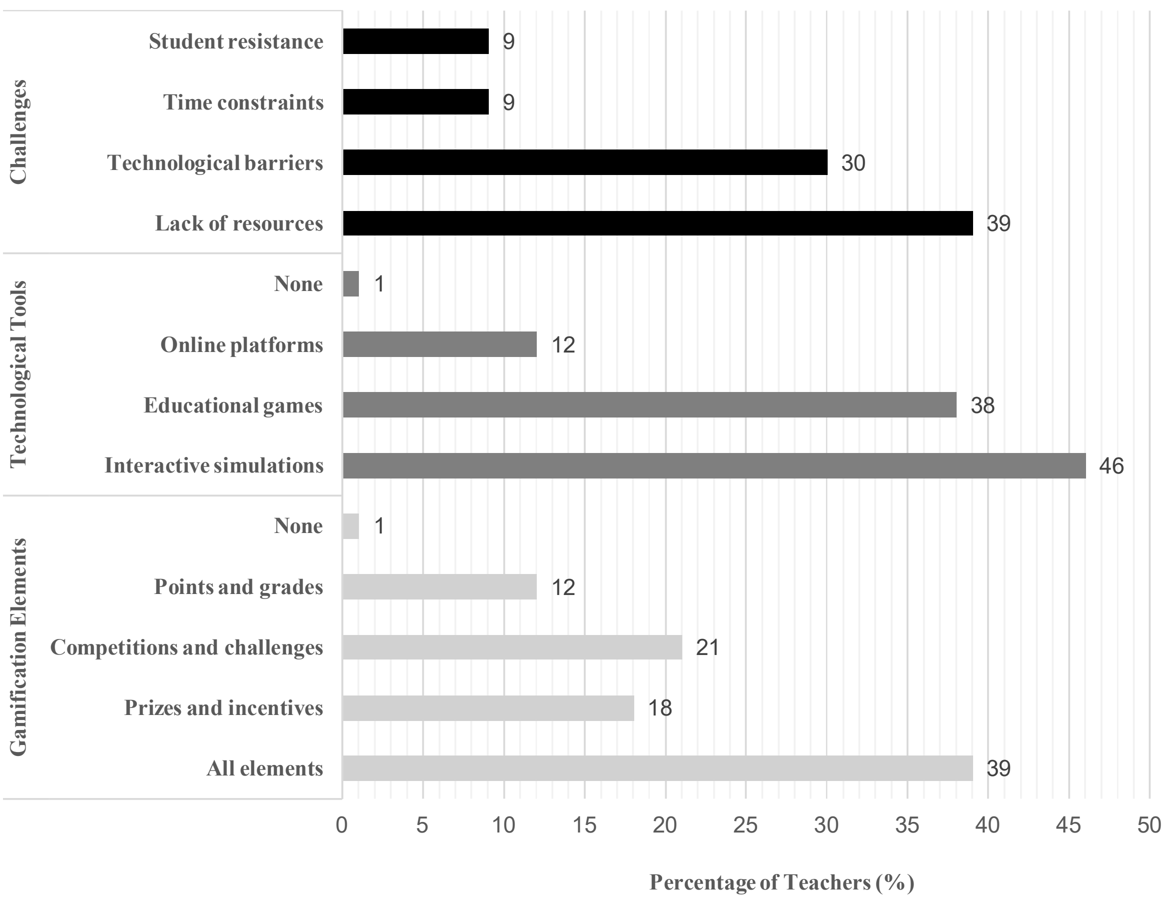
The following results focus on the three questions from the third part of the questionnaire. Responses provide insights into the key elements, technological tools, and challenges related to gamification in physics education, as perceived by Croatian teachers.

Teachers most commonly use competitions, challenges, prizes, and incentives as gamification elements, while a small percentage do not incorporate any (see Figure 1). The most frequently used technological tools are interactive simulations and educational games, though some teachers report not using any (see Figure 1). The main challenges include a lack of resources and technological barriers, with additional concerns about time constraints and student resistance (see Figure 1). Teachers also emphasize the effort required for lesson preparation in gamified environments, with several responses indicating the need for prepared materials, manuals, and training to implement gamification strategies effectively. The remaining percentage of responses up to 100% is not displayed in the graph, as teachers provided varied answers when selecting the "Other" option.

Figure 1
Teachers' Use of Gamification: Elements, Technological Tools, and Challenges



Discussion

This study examines how physics teachers at the primary and secondary levels self-assess their knowledge and beliefs about gamification and the significant differences in knowledge and beliefs based on age, gender, work experience, and school type. It also explores the effective game elements, useful tools, and challenges that teachers identify in implementing gamification.

A total of 230 physics teachers participated in the survey, representing 25% of Croatia's total population of physics teachers. The results indicate that, on average, physics teachers express neutral to moderately positive

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agreement in their evaluation of statements related to both their knowledge of gamification and their beliefs about its effects in the classroom.

The results have revealed no statistically significant differences in teachers' knowledge or beliefs about gamification based on gender. This finding suggests that pedagogical strategies like gamification are perceived similarly across genders, emphasizing its universal applicability in education. This result has aligned with previous studies, such as those by Mårell-Olsson (2019), Mårell-Olsson et al. (2015), and Mejtoft et al. (2017), who have highlighted gamification's potential to enhance student motivation and engagement, while also acknowledging that teachers often lack familiarity with its design and implementation.

Although age does not significantly influence teachers' knowledge of gamification, there is a trend toward significance in their beliefs, indicating that age might shape perceptions to some extent. This is consistent with findings by Brooks et al. (2019), who have observed that teachers' positive beliefs about gamification are influenced by its ease of use and the motivation it fosters in students, highlighting motivation as a key determinant of the effectiveness of this approach. This observation aligns with Kovalenko and Skvortsova (2022), who have reported that one in five teachers expressed negative attitudes toward certain gamification techniques, often due to difficulties in sustaining student engagement and ensuring the desired educational outcomes. Similarly, Brooks et al. (2019) have found a lack of gamification knowledge among teachers, which aligns with the current study's results on Croatian teachers.

Work experience, however, has been found to significantly impact teachers' beliefs, with more experienced teachers demonstrating stronger convictions about the value of gamification. This aligns with the findings of Sajinčič et al. (2022), who have noted that experienced teachers are more familiar with gamification and have had more opportunities to use it in their classrooms.

The analysis also indicates that the type of school (primary or secondary) does not have a significant effect on teachers' knowledge or beliefs about gamification. This might suggest a similar level of competence of physics teachers on gamification for primary and secondary schools. Mee Mee et al. (2020) have emphasized the importance of providing all teachers with appropriate materials and tools to support gamification, regardless of their school. This finding highlights the need for universally applicable strategies to address teachers' diverse needs in both primary and secondary education.

Regression analysis has explored the relationships between demographic factors and teachers' knowledge and beliefs about gamification. Although no significant predictors of knowledge have been identified from the demographic factors, both work experience and age have been found to have a significant influence on teachers' beliefs. Specifically, teachers with more experience tended to have stronger beliefs in the effectiveness of gamification. These results are consistent with those of Liu et al. (2023), who have reported that demographic factors such as gender, age, work experience, and school type did not significantly impact the effectiveness of gamification but have noted that experience influences teachers' beliefs toward its use. The finding that experience contributes to stronger beliefs about gamification underscores the importance of mentoring programs, where experienced teachers can share their expertise with less experienced colleagues.

Responses to the open-ended questions in the questionnaire provide additional insights. Teachers have identified rewards, competitive elements, and technological tools as the most effective game elements for physics education. Specifically, 39% of teachers have favored all proposed game elements, while 18% have highlighted prizes and incentives, 21% have emphasized competitions and challenges, and slightly more than 12% note points and grades. Only 1% of respondents have reported not using any game elements in their lessons. These findings indicate that while teachers recognize the potential of gamification to enhance engagement, its practical implementation varies widely.

Technological tools are a key focus, with 46% of teachers reporting the use of interactive simulations, 38% utilizing educational games, and 12% relying on online platforms to support gamification. These findings highlight the integration of gamification with digital resources as a prevalent teaching method. However, some teachers express concerns about the artificiality of simulations compared to real experiments, suggesting that hands-on activities may be more effective in deepening students' understanding of physics concepts. This has also been highlighted in a study on physics teaching in Croatia during the pandemic, where many physics teachers, despite the mentioned concerns, have adapted to the circumstances using various digital tools (Štibi et al., 2021).

In this study, teachers have also identified several challenges in implementing gamification. The most significant barrier was the lack of resources (39%), followed by technological challenges (30%), time constraints (9%), and student resistance (9%). The need for training and prepared materials is a recurring theme in teachers' responses, with many emphasizing the importance of accessible resources and instructional guides to facilitate gamifica-

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tion. For instance, one teacher noted, "It takes time and research, but it would be great if there were some kind of manual with helpful ideas and tips." These findings align with Barringer et al. (2018), who have emphasized that while gamification can enhance learning, it must be complemented by addressing students' alternative conceptions and incorporating iterative design improvements and reflective practices into gamified tools. Without these additional considerations, gamification risks being superficial and less effective in fostering deep conceptual understanding. Another teacher in our study pointed out the challenge of creating well-designed games tailored to physics education, noting, "There is a lack of consistently designed and tested games specifically for teaching physics, as well as insufficient technological support for dynamic, interactive input exchange in the classroom."

The findings from this study highlight that while many Croatian physics teachers recognize the potential of gamification to engage students, its success depends on thoughtful implementation and alignment with learning objectives. This aligns with Lampropoulos and Kinshuk (2024), who have reported that gamification demonstrates strong cognitive benefits, although its effects on motivation and behavior are less consistent. In addition, Fleissner-Martin et al. (2024) have emphasized the value of gamified strategies in cultivating essential skills such as creativity and critical thinking, underscoring the need for professional development to equip teachers with effective implementation strategies.

The results of this study also underscore the importance of addressing practical barriers to gamification, including the need for training, resources, and technological support. While gamification has significant potential to enhance student engagement and motivation, its success depends on equipping teachers with the necessary tools and knowledge to implement it effectively. Future research should focus on developing comprehensive training programs and resources tailored to the needs of physics teachers, enabling them to overcome these challenges and maximize the benefits of gamification.

Conclusions and Implications

The present study examines Croatian physics teachers' knowledge and beliefs about gamification. The findings indicate that while teachers acknowledge gamification's potential to engage students, they report limited participation in gamification training, pointing to a gap in professional development. Teachers are more comfortable using technological tools like interactive simulations and educational games but are less convinced of gamification's effectiveness in developing practical physics skills. Demographic factors like age and work experience significantly influenced teachers' beliefs, with older and more experienced teachers demonstrating stronger positive beliefs toward gamification. However, gender and school type do not significantly affect teachers' knowledge or beliefs.

Further findings indicate that teachers recognize various effective gamification elements, with prizes, competitions, and points frequently cited as key components. Regarding technological tools, most teachers reported using interactive simulations, educational games, and online platforms to support gamification. The study also identifies several significant challenges in implementing gamification, such as insufficient resources, technological barriers, time constraints, and student resistance. These challenges highlight the need for enhanced training, support, and resource availability to facilitate the integration of gamification into classrooms. Additionally, teachers emphasize the importance of practical guides and well-designed materials to support successful implementation.

Therefore, the implications of this research extend to both policy and practice. Educational institutions should invest in comprehensive training programs to improve teachers' knowledge of gamification and foster collaboration. Providing ready-to-use teaching materials and technological support can help teachers integrate gamification more easily. Mentorship between experienced and less experienced teachers will further strengthen its adoption.

Although the study provides valuable insights into gamification in physics education from the perspective of teachers, it also identifies areas for future research. The survey's brevity limits the depth of teachers' experiences, so future studies should incorporate qualitative approaches to explore how gamification impacts teaching and learning. Longitudinal studies are needed to assess the long-term effects of gamification on students' academic achievements, beliefs toward physics, and engagement. Research on its impact on diverse student populations, including those with special educational needs, would further enrich understanding.

The research presented here contributes to the growing body of knowledge on gamification and highlights its potential to make physics education more accessible and effective for diverse learners. Finally, the full potential of gamification as a pedagogical tool can be realized by overcoming challenges and harnessing teachers' positive beliefs. With the right support, gamification can transform physics classrooms into dynamic, engaging environments that foster curiosity, participation, and a deeper understanding of the subject.

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Declaration of Interest

The authors declare no competing interest.

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